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Carbon management at the household level: a definition of carbon literacy and three mechanisms that increase it

Rachel A. Howell

School of Social and Political Science, University of Edinburgh, Edinburgh, UK

Full address for correspondence: The University of Edinburgh, School of Social and Political Science, Chrystal Macmillan Building, 15a George Square, Edinburgh EH8 9LD, UK

Tel: +44 131 6511384

Email address: rachel.howell@ed.ac.uk

ORCID: 0000-0002-0932-6491

Personal webpage: http://www.sociology.ed.ac.uk/people/staff/rachel_howell

LinkedIn: <https://www.linkedin.com/in/rachelhowell/>

Abstract

In order to engage in carbon management at the household level, individuals need to understand how their everyday activities contribute to greenhouse gas emissions, and how they can reduce their personal carbon footprint. This implies a need for ‘carbon literacy’, a term that has emerged in the literature in the last few years without being formally defined. This paper proposes a definition of carbon literacy and compares this with other, related concepts. I then present the results of two qualitative studies that reveal how three mechanisms help to increase carbon literacy: energy monitoring; carbon footprint statements; and peer/social learning through sharing information, skills and resources with others. The different aspects of carbon literacy that these mechanisms contribute to are highlighted. Especially notable is the significance of carbon footprint statements, which enable understanding of the relative emissions associated with different activities, and the value many interviewees placed on learning within a group. These two mechanisms enhance the impact of energy monitoring by individuals, which is part of the focus of schemes such as the introduction of ‘smart’ energy meters in several countries. The implications of these findings for policymakers and others who wish to promote carbon literacy are discussed.

Keywords

Carbon literacy; carbon footprint; energy monitoring; carbon calculator; greenhouse gas emissions; climate change mitigation; social learning

1. Introduction

There is an increasing drive to encourage individuals to understand how their lifestyles and everyday activities contribute to greenhouse gas (GHG) emissions, and how they can reduce their personal ‘carbon footprint’ (the amount of GHGs emitted by an individual’s activities during a specified time period). This can be seen in government initiatives (such as ‘Act on CO₂’ and the Low Carbon Communities Challenge in the UK), traditional and social media (e.g. Berners-Lee 2017 in the UK; Stellin 2013 in the USA; Vitta 2016, in India) and campaigns by environmental organizations (e.g. no2co2 in India; 10:10 in the UK; WWF worldwide). The Paris Agreement potentially makes significant emissions reductions, including at individual/household level, more of a national and international priority.

Emission reduction targets such as those set by the UK and Scottish Governments (HM Government 2008, 2009) will require behavioral changes on the part of the public in order to meet them (Stern 2006), especially given the high proportion of emissions attributable to individuals/households (Druckman and Jackson 2009). These emissions are related to individuals' (deliberate and habitual) behavior and not merely to factors such as the thermal efficiency of different houses (Gram-Hanssen 2010). This likely pertains to many other countries with GHG emissions reduction targets. Developments such as the growing use of smart meters and household microgeneration technologies are increasing the potential for householders to access real-time information about energy use and associated emissions, and to make decisions based on this information.

This situation implies/requires development of 'carbon literacy', a term that has emerged in the literature during the last few years without being formally defined. This paper proposes a definition of carbon literacy and compares this with other, related concepts (section 2). Section 3 discusses what the literature tells us about levels of carbon literacy among the public. The rest of the paper then focuses on two qualitative studies which reveal three mechanisms that participants reported increased aspects of their carbon literacy. Section 4 details the method and participants involved in this empirical research, and section 5 presents the findings. Section 6 discusses these results and their implications for policymakers and others (e.g. non-governmental organizations) who wish to promote carbon literacy. Section 7 concludes the paper with a summary and suggestions for future research.

In what follows I adopt shorthand terminology that reflects common usage: 'carbon' is generally used in place of 'carbon dioxide' (CO₂) in lexical compounds such as 'carbon footprint', 'carbon emissions' and 'carbon allowance', which often encompass other GHGs too.

2. What is 'carbon literacy'?

The term 'carbon literacy' has been used in several papers over the past decade (e.g. Bottrill 2007; Capstick and Lewis 2010; Parag and Strickland 2009; Roberts 2006; Seyfang 2007; Seyfang, Lorenzoni, and Nye 2007; Whitmarsh et al. 2009; Whitmarsh, Seyfang, and O'Neill 2011; Howell 2012), but it has not been specifically defined, nor its components clearly identified. The nearest attempt at a definition is by Seyfang (2007, 13), who states that 'really understanding carbon budgets and how to manage them through behavior change' is 'what we might call "carbon literacy" as an analogue to financial literacy', and that this is a 'previously unidentified and undeveloped competency'. This designation is given in a paper on Personal Carbon Trading, hence the reference to carbon budgets; as these are not everyday realities and require explanation, it is not the most suitable definition of carbon literacy for general use.

Lorraine Whitmarsh and colleagues, adapting work by Seyfang, Lorenzoni, and Nye (2007), have defined a related but broader concept of 'carbon capability', as 'The ability to make informed judgements and to take effective decisions regarding the use and management of carbon, through both individual behavior change and collective action' (Whitmarsh et al., 2009, 2; Whitmarsh, Seyfang, and O'Neill 2011, 59). They distinguish carbon *capability* from carbon *literacy* by explaining that 'carbon capability implies an understanding of the limits of individual action and where these encounter wider societal institutions and infrastructure, and so prompt the need for collective action and other governance solutions' (Whitmarsh, Seyfang, and O'Neill 2011, 59). Their definition reflects the view that an individual's ability 'to take effective decisions regarding the use and management of carbon' depends on societal infrastructure, government policies and so on, and that carbon capable

people will understand this and seek to influence such structures so as to increase their ability to manage their carbon emissions.

Horng et al. have developed a 'low-carbon literacy scale' for use in the tourism industry, and define 'low-carbon literacy' as 'knowledge and understanding of energy conservation and carbon reduction and the incorporation of this literacy into everyday life' (2013, 256). Their scale comprises seven constructs including not only knowledge of low-carbon issues but also attitudes and values, action intent, and action strategy. Thus their definition involves normative assumptions that 'low-carbon literacy' entails holding certain attitudes and values and actively seeking to reduce GHG emissions, rather than simply having the knowledge and skills to do so. This is also true of The Carbon Literacy Project (CLP), based in Manchester, UK, which offers carbon literacy training to various organizations in the city. They define carbon literacy as 'An awareness of the carbon costs and impacts of everyday activities and the ability and motivation to reduce emissions on an individual, community and organisational basis.'¹

In this, the definitions by Horng et al. and CLP are similar to common conceptions of 'environmental literacy' and 'ecoliteracy', which include 'affect' (positive attitudes towards action) and 'environmentally responsible behavior' (McBride et al. 2013). However, 'ecological literacy' focusses on knowledge and skills and does not tend to incorporate attitudes and behavior (McBride et al. 2013), while definitions of 'energy literacy' range from those that focus on knowledge and understanding (Dwyer 2011) and competence in making sense of energy use (Schwartz et al. 2013) to those that also require positive attitudes and actions/behaviors towards energy conservation (DeWaters and Powers 2013).

Definitions of 'literacy' clearly encompass skills and not merely knowledge; literacy involves being able to *do* certain things (such as read and write) and thereby participate in society (Mason and Wilson 2000; UNESCO 2004). However, a person is not judged less literate because of what she chooses to read or write, unless her choice indicates lack of ability. Similarly, although managing one's finances competently is considered part of being 'financially literate', there is no expectation that financial literacy necessarily includes choosing 'ethical' investments or managing one's money for the common good rather than one's own narrow self-interest. Hence, an analogous definition of 'carbon literacy' would not include any assumptions about how persons possessing such a skill choose to use it.

Despite the fact that carbon literate individuals should be aware of the case for taking action to reduce GHG emissions, they might decide not to (e.g. due to free rider concerns) or be unable to do so (e.g. because of social or infrastructural constraints). These are examples of the knowledge/value-action gap which has been much discussed in literature on encouraging behavioral change (e.g. Alcock et al. 2017; Barr 2006). Policymakers should therefore be aware that enhancing carbon literacy may not necessarily result in emissions reductions. I argue that defining 'carbon literacy' without making normative assumptions about attitudes or action is necessary, as it allows for the use of the concept to assess whether individuals have the personal abilities to make informed choices within the context in which they find themselves. It enables us to answer the question 'Does this person possess the knowledge and skills to reduce his carbon footprint given the options available to him?' without complicating the issue by having to consider whether he is using such abilities, and if not, why not.

The definition of carbon literacy I propose is based on the definition of financial literacy suggested by Mason and Wilson (2000), as this is developed following a comprehensive discussion of the meaning of literacy and can be appropriately modified. The definition is suitable for the empirical purposes for which a conception of carbon literacy is required (e.g. evaluation of the effectiveness of interventions designed to increase individuals' carbon literacy). Thus:

Carbon literacy is an individual's ability to obtain, understand and evaluate the relevant information necessary to make decisions with an awareness of the likely consequences regarding greenhouse gas emissions.

The definition relates to GHG – rather than CO₂ – emissions because some activities (such as eating meat and flying) have significant non-CO₂ emissions associated with them. Such emissions may be expressed using carbon dioxide equivalent (CO₂e) units or simply be included in the informal label ‘carbon emissions’.

Distinguishing carbon literacy from climate change mitigation actions (whether lower-carbon behaviors or campaigning) should not be seen as diminishing the importance of those desired outcomes of carbon literacy. The objective of promoting carbon literacy is to stimulate lower-carbon behaviors and lifestyles. This implies that carbon literacy must go hand-in-hand with knowledge and understanding of the impact of GHGs on the climate and why it is necessary to reduce them. Thus carbon literacy could be regarded as a subset of the knowledge and skills associated with the broader concept of environmental literacy (see McBride et al. 2013).

An aspect of being able to ‘make decisions with an awareness of the likely consequences’ is knowing how to reduce one’s GHG emissions, and what the most effective mitigation actions would be, even though the definition does not require such knowledge to be put to use. Components of carbon literacy that may contribute to this and reasonably be considered part of the definition include: understanding the sources of GHG emissions as these relate to everyday activities; appreciating the relative impacts of different activities, fuel choices etc.; and possessing the skills and knowledge (including tacit knowledge, see Darby 2006) to operationalize these understandings when making behavioral and lifestyle choices. These are not necessarily the only elements of carbon literacy, but they will be the focus of this paper.

3. Literature relating to public carbon literacy levels

3.1. Public understanding of GHG emissions and the relative impacts of different activities

There is more research into what the general public understand about the causes of climate change (i.e. sources of GHG emissions) than on what they know about solutions (i.e. how to reduce their GHG emissions). Public knowledge of the sources of GHG emissions appears limited (e.g. Lorenzoni and Pidgeon 2006; Reynolds et al. 2010), and emissions are rarely linked to personal actions and lifestyle choices (Whitmarsh et al. 2009, Whitmarsh, Seyfang, and O’Neill 2011). There could be an element of denial involved here as a psychological defense against unpleasant feelings such as guilt (Doherty and Clayton 2011; Opatow and Weiss 2000). It is notable that several of the behaviors that survey respondents are least likely to recognize as causes of GHG emissions are those that the public are least prepared to address in their own lifestyles (Anable, Lane, and Kelay 2006); causality could run either way in this situation.

Additionally, individuals often do not understand the relative impact of different activities/appliances on GHG emissions (Hargreaves, Nye, and Burgess 2010; Sharp and Høj 2009). In particular, while driving a car is generally recognized as a contributor to GHG emissions (Bulkeley 2000; Truelove and Parks 2012), the significance of flying (Anable, Lane, and Kelay 2006; Becken 2007) and meat-eating (Truelove and Parks 2012; Whitmarsh, Seyfang, and O’Neill 2011) is underestimated, and people often assume that energy use of appliances is simply proportional to their size (Steg 2008). Recycling, which has relatively low potential for emissions reductions, is identified by a significant proportion of survey respondents as the action that would be most effective in reducing climate change (Downing and Ballantyne 2007; Scottish Government 2008), and is regarded by some people as

offsetting high-carbon behaviors such as flying (Scottish Government 2011; Barr et al. 2010). Again, there may be an element of ‘wishful thinking’ in these responses. Additionally, many campaigns focus on ‘small actions’ (Segnit and Ereaut 2007), or offer long lists of suggested actions unranked by effectiveness (Gardner and Stern 2008), which may confuse people or mislead them to believe that small changes can have significant effects.

3.2 Smart meters, energy monitoring and carbon calculators

Smart electricity and gas meters are due to be installed in all homes in Britain by 2020. The UK government hopes that this will help householders to understand and reduce energy use. Reductions in demand of approximately 3% were found in trials of smart metering combined with feedback from in-home displays (IHDs; Darby 2013). Schwartz et al. (2013) provided households with Home Energy Management Systems comprising visual displays of information from smart meters and plugs. They found that this improved energy literacy as they defined it, as participants developed more understanding of household electricity consumption. They also changed their behavior, appliances and appliance configurations as a result of their improved energy literacy.

Monitors and smart meter IHDs which offer users the ability to measure carbon emissions associated with energy use can additionally promote carbon literacy (Schwartz et al. 2013). However, a study by Hargreaves, Nye, and Burgess (2010) of householders using a variety of monitors found that most preferred to view data displayed in monetary terms rather than carbon or kilowatt hours, which were seen as meaningless (see also Chatterton et al. 2009). Although participants were not very interested in total electricity usage, they were keen to discover which of their appliances used most electricity and found comparisons of different appliances useful. Energy monitor usage declined after initial interest. A report on early learning from the UK’s smart meter program states that 6 in 10 were still using their IHD between six months and two years after installation, and householders taking a ‘monitoring approach’, looking at trends over time, were more likely to benefit from smart metering (Darby et al. 2015). The Department for Energy and Climate Change (DECC) has said that it intends to encourage such a monitoring approach (DECC 2015).

There are a large number of web-based carbon calculators available to help people calculate their carbon footprint and understand how to reduce it (Juvan and Dolnicar 2014). Chatterton et al. (2009) found that some individuals using carbon calculators for the first time appreciated the information they provided and expressed increased interest in reducing carbon emissions. However, only one in ten respondents in a UK survey had used a carbon calculator (Whitmarsh, Seyfang, and O’Neill 2011), while Sharp and Wheeler (2013) found only seven per cent of participants in their Australian study had estimated their carbon footprint.

An assessment by Bottrill (2007) of thirty online carbon calculators concluded that most fall short in various ways, including accuracy and ongoing monitoring of energy use; providing meaningful feedback and guidance; and offering opportunities to connect and share information and experiences with other users. Admittedly this assessment was conducted ten years ago and carbon calculators may have improved since then. I have not been able to find a more recent evaluation that is as comprehensive as Bottrill’s, but a limited analysis of carbon calculators in the context of air travel by Filimonau (2012) concluded that the quality and reliability of carbon calculators needs to be improved, while a recent study by Juvan and Dolnicar (2014) revealed that participants in Australia and Slovenia found carbon calculators difficult to use to assess the impacts of their holiday travel decisions.

3.3. Other means to improve carbon literacy

Various attempts have been made to translate concepts related to GHG emissions into user-friendly metaphors to aid understanding. For example, the concept of a 'carbon footprint' has now been popularized (see e.g. Berners-Lee 2017; Stellan 2013) and over half of the respondents in a UK survey in 2008 stated that they know 'a lot' or 'a fair amount' about the term (Whitmarsh, Seyfang, and O'Neill 2011), although in Hong Kong, McKercher et al. (2010) found that only between seven and thirteen per cent of respondents are familiar with it. Personal emissions reductions have been variously characterized as a 'carbon detox' (Marshall 2007), 'carbon diet' (Siegle 2007) and 'carbon fast' (Vaughan 2009). Similarly, efforts have been made to name measures of emissions so as to avoid using alienating and poorly understood chemical formulae: for example, 'carb' (100g CO₂; Siegle 2007); 'carbo' (1kg CO₂e; Marshall 2007); 'carbon point' (a metaphor associated with store loyalty points; 1kg CO₂e; Howell 2007).

It has also been suggested that carbon labelling of products (similar to nutritional labelling of food) and emissions information provided on household energy bills and transaction receipts for goods such as petrol/diesel and flights could help develop carbon literacy (Parag and Strickland 2009; Howell 2012). Testing carbon labels for food products, Sharp and Wheeler (2013) found that householders prefer formats that use a 'traffic light' color system, and show emissions relative to other products.

4. Method and participants

The data on which this paper is based come from two research projects. The first involved semi-structured interviews ($n = 23$) carried out to investigate the opinions and experiences of members of UK Carbon Rationing Action Groups (CRAGs), who were recruited via email contacts gained from the CRAG website (no longer available) (see Howell 2012). The second study explored the narratives of change of individuals who self-identified as having adopted lower-carbon lifestyles, through in-depth interviews ($n = 16$) with people recruited from CRAGs, Carbon Conversations participants, and viewers of a climate change film (Howell 2013).

CRAGs are groups of people who voluntarily commit to limit their greenhouse gas emissions by living within an annual 'carbon allowance'. CRAG members (CRAGgers) record their emissions from agreed sources/activities (generally direct emissions from home energy use and transport) using a carbon calculator or a set of conversion factors approved by the group, report these emissions to the group (usually quarterly), and support each other in their attempts to reduce their emissions through use of energy efficiency/renewable energy generation technologies, and/or behavioral changes. (For more information on CRAGs see Howell 2012.) Carbon Conversations comprise six meetings involving group activities and discussion about climate change and carbon footprint reductions (see Randall 2009). Participants monitor their home energy use and calculate their travel-related emissions; they also submit data which is used to provide each participant with a personalized carbon footprint calculation at the beginning of the course.

The interviewees were 16 women and 18 men, five of whom were interviewed twice, once for each of the different studies described above. They ranged from a student in his early 20s to retired people over 60 (up to 82 years of age); the majority were professionals in their thirties to fifties. Seven interviewees had participated in Carbon Conversations, 23 were members of 10 different CRAGs, and four were not involved in either of these groups. This was not a representative sample of the 'general public' but the interviews provide useful information about elements of carbon literacy and how it may develop through particular mechanisms/processes.

Most of the interviews were conducted face-to-face in venues that suited the interviewees; five were held by phone. Two couples were interviewed as couples; the other interviews were one-to-one. Participants were offered £20 for their time.

The interviews were digitally recorded and transcribed in full, then analyzed and coded using both broad pre-determined themes (including ‘carbon literacy’) relating to the structure of the interviews, and detailed, nuanced codes that were developed during an iterative process of data examination and analysis.

5. Results

This section presents data from the interviews, which provide evidence of three different mechanisms that increase carbon literacy. All names used are pseudonyms. Labels identify interviewees who belonged to a CRAG (CRAGger), took part in Carbon Conversations (CC), or neither (other).

5.1. *Monitoring energy use*

The first mechanism for improving carbon literacy that I identified from the data is energy- and fuel-use monitoring. Many of the interviewees mentioned monitoring their energy use in various ways, from simple paper and pen notes to using sophisticated energy monitors:

I know over the last fourteen years exactly how many miles I’ve done in this car every year... (David, CC)

And apart from the odd occasion when I’ve forgotten or been distracted or been away, the meter has been read every Thursday; the electrical meter. (George, other)

...when a bottle of gas runs out as it has today, [...] we write it down on the calendar so we’ve got an idea of how long they’re lasting. (Lara, CRAGger)

I’ve got a little meter, which is very cheap to buy, and I’ve taken it round everything in the house. (Steve, CRAGger)

Participants reported that using electricity monitors or carbon calculators to compute the emissions associated with recorded energy use had led to an increased understanding of the sources of emissions and the impacts of everyday practices:

...it was only really when I joined the CRAG and actually started *measuring* things that I realized what my own impact was [...]. We have our heating down really low, we live in this flat which is insulated from top and bottom and the sides by other people, and we have thick curtains, and I felt we didn’t have much of an impact because I didn’t really bear in mind the use of the car and the flying... (Evie, CRAGger)

I could just go round this room, telly, DVD, video, hi-fi, telephone, gas fire, and pretty much tell you how much carbon would be used by each one in an hour or a day or something. (Steve, CRAGger)

...having two showers a day also increases [your carbon footprint]. And all these kind of things, the little things that add up. I remember how surprised I was. You only think about petrol prices, I think... (Eszther, CC)

I used to assume that going by boat was really light on the carbon, [...] then I realized that ferries seem to be, if you can find a reliable figure, it seems to be worse than long haul flying. (Bob, CRAGger)

Monitoring energy use and seeing the figures not only helped promote factual knowledge, but made energy use and associated emissions more ‘concrete’ and noticeable:

CO₂... it’s quite an abstract concept isn’t it, to grasp [...] I needed something visual in my mind or some figures on a bit of paper to bring it to consciousness so that was good. (Lara, CRAGger)

I had an energy monitor, I could tell exactly how much I was using; I would be very conscious to use as little as possible. I started to become very aware how much energy a laptop would use... (Luke, CC)

As intimated by Luke, above, this had led to changes in attitudes and behavior:

I'm less keen on [commuting] again, because even though I was only using the train, when I actually totted up what a sixty mile commute by train does to your carbon footprint, it's not pretty. (Em, CC)

I was amazed at how much these things on standby used. Since I hardly ever watch television anyway, I turn it off the wall and it stays off now as a result of that. (David, CC)

However, even motivated people such as these do not all find energy monitoring easy. An interviewee who had been to one CRAG meeting but decided not to join gave as one reason:

I've just never managed to get my head around reading meters and kilowatt hours and things so, God, I sat there looking at spreadsheets going, 'I just don't get it and I don't have a brain that functions that way and I'm not interested really in sitting going through my bills'... (Claire, other)

Linda, who had helped set up a workplace CRAG said that 'the main challenge has been around people getting information back', which she attributed to time pressures, while a long-term CRAGger said that

...one of the things I've learnt in the CRAGs was that people are not that interested in numbers and counting, and the sooner we can get away from that and move to a system where everything's internalized in prices and normal economic language, then it'll be better for everybody. (Ben, CRAGger)

Another interviewee also expressed reservations, but had found a solution:

What I liked least was things that involved measurement; I found that much more difficult than I had expected. So the exercises about keeping a record of what transport you used, and your gas and electricity consumption. But there was a solution to that latter one, and that's sign up with iMeasure, which made all the difference. (Prue, CC)

Other interviewees also mentioned iMeasure, an energy and carbon monitoring website², and similar online tools such as Carbon Account³.

Energy use monitoring also seems to suffer from a bit of an 'image' problem: David (CC) described his interest in an electricity monitor as 'nerdish'; Em (CC) spoke of having 'my little graph' of meter readings, which suggests she didn't wish the graph to seem to have too big a place in her life; Ben (CRAGger) interrupted what he was saying about his energy consumption to assure me, 'I'm not completely obsessed about it; I probably look at my meter at least once a week, but not every day.'

5.2. Comparing relative impacts of different activities: the importance of comprehensive carbon footprint statements

It should be stressed that in general it was not raw figures alone that helped, but *comparisons* between different appliances and activities. Thus, tools (such as carbon footprint calculators/statements) that give information about the relative impacts of a range of different activities are a second, very important, mechanism for increasing carbon literacy. Energy monitors, for example, were used to discover the appliances that used *most* energy:

I have been taking measurements just to see what household equipment uses the most energy. And one of them was an electric heater. Which I am absolutely adamant that that only come on under extreme circumstances. (Daniel, CRAGger)

Interviewees found that carbon footprint calculations covering all their activities (or at least all their direct energy use) over a period of time, enabling understanding of the relative emissions associated with different sectors (food, travel etc.), were very revealing:

I knew where my emissions came from before but now know the relative between, especially things like gas and electricity, car. (Eleanor, CRAGger)

...it has really shown me how much taking an aeroplane flight to Egypt my last holiday had such a big impact on my overall carbon emissions, it was surprising. Something that you're aware of, that it's going to be bad, but until I saw that I didn't realize how much it was and yeah, it's just helped really, visualizing what causes the most problems and what doesn't... (Joe, CRAGger)

This realization about the comparatively large impact of flying, facilitated by carbon footprint calculations, was a recurrent theme. Daniel said that even though he was an energy professional, if somebody had asked him before he joined his CRAG what proportional impact a return flight to Paris would have on his carbon footprint, he couldn't have answered, but now he knows 'what the split is', having seen his quarterly statement. CRAGger Ella said that 'doing the carbon footprint three years ago and realizing what a massive impact flying had, that was quite an eye opener', while Evie, another CRAGger, stated: 'I suppose the shocker when we looked at our carbon footprint first was, we had a huge a footprint from travel, and most of it was air'. Ella and Evie had both committed to avoiding air travel as a result.

Carbon footprint calculations also aided understanding of emissions that are embedded in products and services, and therefore not easily monitored, such as the impact of food on one's carbon footprint:

I like eating and making food, but before I did the Conversations it was an area I just didn't consider, I really didn't. I didn't think it was all that significant. I was thinking it's travel and the house that would be the big ones. (Paul, CC)

Comparisons were made not only between different activities, but different times of the year, different living situations, and with the concept of a 'fair share' of global emissions:

So for example this year I know that gas consumption will be more than last year because I've been checking every couple of months... (Liz, CRAGger)

I'm interested, especially at the moment as I have just moved, to see the difference between the times of year and living ...you know, I was living on my own in a flat and then I moved in to share a flat so it is interesting to see the difference... (Ben, CRAGger)

We have learned what a commute from Glasgow to Edinburgh is in carbon terms and we know what our fair share globally is, and so we can see how many commutes make up our fair share [...] we are much more carbon literate in that sense. (Ben, CRAGger)

As with energy monitoring, carbon footprinting and other comparisons helped interviewees decide where to make changes, as well as what may not be so effective:

[Doing the calculations] definitely makes me think about what's the most effective thing to do, so I could spend a lot of money getting an induction hob but actually it's more effective to sort out the loft insulation. (Ella, CRAGger)

...we have to do the big things [...] people think 'Oh, I'm turning off the plug; I'm not leaving the telly on and I only have one computer.' These things actually don't contribute as much as people think. (Eszther, CC)

Having said this, interviewees were aware of potential inaccuracies in carbon calculators. CRAGger Justin said 'these devices, these tools, are not calculators, they're estimators, they're guesstimators, they are a best guess at it and there's no way that they are accurate', giving as an example the fact that the government's 'Act on CO₂' calculator only calculated the CO₂ emissions associated with flights and did not include a multiplier to reflect the greater radiative forcing produced by planes through vapor trails and emissions of particulates and NO_x (see Cairns and Newson 2006).

5.3. Group discussions and information/skills/resource sharing

The third mechanism that emerged from the interviews as increasing carbon literacy is sharing of information, and peer/social learning (learning from peers through either direct instruction or via observation, imitation, and modelling). Group discussions raised awareness about GHG emissions even from activities that were not being monitored:

I have learnt much more about climate change since being in a CRAG than I'd learnt in the previous 15 years or so. Now we discuss the issue about food, which is a really big issue. (Ian, CRAGger)

I remember we had a discussion once about low carbon footprint burials. [...] Things like that have made me think... (Oliver, CRAGger)

They also raised awareness of ways to reduce emissions, including some specific, local knowledge that it might be hard to find through more general information channels:

I certainly think that I have found out *information* at the CRAG that I wouldn't necessarily have found out otherwise, just from people trying things out in their own houses and telling us. Insulation materials, where to find things, gadgets that help, really practical basic things like that... (Steve, CRAGger)

I've had some very useful discussions with people who've known about practical contacts of where to go for solar panels, where not to go for solar panels, and met people with specific areas of expertise. (Bob, CRAGger)

Oh it's been great to be a group because we've been able to share loads of information about ethical sourcing, green electricity. What's the cheapest tariff? Who are good? Who aren't? (Lara, CRAGger)

This included not only conversations but demonstrations; for example, Prue explained that one of the facilitators of her Carbon Conversations group put her in touch with somebody who had installed a particular type of double glazing at home, so she was able to go and see it. Prue and her husband now open their home to others to demonstrate the energy efficiency measures and photovoltaic panels they have installed (cf. Hamilton and Killip 2009).

The CRAG website was also mentioned, being described as 'a mine of information' and 'a resource that we wouldn't have on our own' by CRAGgers Justin and Ben respectively. This latter comment indicates one reason why being part of a group was considered so important: it reduced the amount of work for individuals, who would otherwise 'be hunting for stuff' (Ben, CRAGger). It also allowed individuals who had less knowledge easy access to those with more; as CRAGger Dave said, 'we've got people who are experts in different areas within the group.'

Being part of a group enabled sharing of resources and skills as well as information. For example, interviewees who had been involved in Carbon Conversations mentioned how useful it had been to borrow energy monitors from the facilitators. Some interviewees felt that interaction with others is *necessary* to enable people to use information. For example, Ethan found that being in a CRAG meant that people with 'technological know-how' were available to help him make sense of information that alone he just found confusing. Another interviewee mentioned a local council plan to distribute energy monitors in the area and her fear that 'they would buy all the technology, they'll give it out and nothing will happen.' She explained:

...I think actually it's really important to be in groups. Just thinking of how people learn, so much of how people learn, it's from somebody else, from somebody else showing you how to do something. Somebody else listening to you talk about something, exchanging ideas with somebody else who's like you. (Ella, CRAGger)

Finally, there was the suggestion that groups produce better ideas than individuals:

...you can read as much as you like, but if you're in an environment where there's a bunch of people and you're bouncing ideas off each other that's where you get the creativity, that's where you get the brilliant new idea. You don't get that sat on your own in a room. (Deepta, CC)

6. Discussion

The findings above illustrate how carbon literacy develops through three mechanisms: energy monitoring; carbon footprint statements (and other comparisons); and sharing information, resources and skills with peers. The elements of carbon literacy that these mechanisms contribute to include knowledge of the everyday sources of GHG emissions; understanding the relative impact of different activities; increased awareness of energy use and associated emissions while going about everyday (including habitual) tasks; and appreciation of how to reduce emissions, including what the most effective actions would be, both in terms of 'low hanging fruit' (easy reductions such as no longer leaving appliances on standby) and large reductions (e.g. no longer flying). The three different mechanisms and the elements of carbon literacy that they each contribute to are summarized in Table 1. These are not the only elements of carbon literacy, nor are the three mechanisms discussed the only processes through which carbon literacy improves, simply those that have been highlighted by this research.

[Insert Table 1 about here]

Energy monitoring increased interviewees' awareness and understanding of sources of CO₂ emissions (cf. Hargreaves, Nye, and Burgess 2010; Schwartz et al. 2013); even interviewees who were quite knowledgeable about sources of emissions prior to beginning energy monitoring generally felt they had learned something from doing it. Measuring emissions makes them less invisible and corrects false impressions such as Evie's perception that because she lived in a flat, she must have a small carbon footprint. Of course, this requires skills such as reading gas/electricity meters and/or bills, recording car mileage and other travel details, using a carbon calculator or a set of conversion factors to compute emissions, or the ability to use and understand an energy monitor.

The issue then, especially given the difficulties interviewees outlined, and the apparent image problem it suffers from, is how to encourage energy monitoring and make it simpler. These interviewees were very motivated; we cannot assume that others given energy monitors would use them, as Ella pointed out, and initial interest in using energy monitors does not always last, as mentioned in section 3.2 (and reported in Hargreaves, Nye, and Burgess 2010). Well-situated and simple displays on appliances and car dashboards showing real-time energy/fuel use and emissions might promote carbon literacy among some individuals, since the information would be right in front of them; however, since many people consider carbon emissions data meaningless (Chatterton et al. 2009; Hargreaves, Nye, and Burgess 2010), the question remains whether people would understand or take notice of that aspect of such in-built displays. Carbon labelling on products and receipts could also aid carbon literacy, but needs to offer comparative rather than stand-alone information, in ways that are easy to understand (Sharp and Wheeler 2013).

Ben's suggestion that emissions should be internalized in prices, so that reductions could be achieved if people pay attention to price signals instead of energy/emissions monitoring, would be unlikely to improve carbon literacy. Would this matter, if people nevertheless changed their behavior? Common Cause, an alliance of several non-governmental organizations, argues that in the long run it will not be possible to foster a

sustainable society using self-interest (e.g. by employing financial signals/incentives); appealing to 'intrinsic' motivations and 'self-transcendent values' will be required (Chilton et al. 2012; Holmes et al. 2011).

What really 'added value' to energy monitoring for these interviewees was using the information to make comparisons (as found also by Hargreaves, Nye, and Burgess 2010, and Schwartz et al. 2013), and especially seeing a carbon footprint statement. Those wishing to promote carbon literacy should therefore create more opportunities for individuals to receive/calculate a carbon footprint statement. To do so requires, among other things, further development of accurate, attractive, but simple calculators; as recognized by Justin, those currently available are not ideal (as discussed in section 3.2).

Other types of comparison can also be employed, such as providing energy bills that offer comparisons with neighborhood averages. This is being done by Opower in the USA, leading to energy reductions of up to 3% in the first two years of operation (Darby 2010). These bills use social norms to promote behavioral changes; it is important to give positive feedback to those who are under-average users to prevent them increasing usage to align with the norm (Ayers, Raseman, and Shih 2009; Schultz et al. 2007). However, nothing is as comprehensive, and therefore revealing, as a complete carbon footprint statement.

The final mechanism was the information-, resource-, and skills-sharing facilitated by involvement in groups such as Carbon Conversations and CRAGs (cf. Mulgetta, Jackson, and van der Horst 2010). Gaining information from group members may be preferred to other sources of information because they are known and trusted (Moser 2006; Brent Council 2011), or, as Ella argued, similar to oneself (Kahan 2010). They can offer practical help, demonstrate new technologies, as Prue experienced, and model new behaviors, which is especially effective for promoting home energy conservation (Osbaldeston and Schott 2012). Furthermore, groups reduce the amount of work required of individuals to find information, allowing it to be shared out and/or done by those with most interest and ability, and making use of opportunities for peer/social learning and development of necessary tacit knowledge (Darby 2006). Even group-based tools such as the CRAG website are perhaps more helpful and accessible than similar tools, such as other websites, because 'buy in' to the movement encourages engagement with its website.

Such groups are likely always to be the preserve of a small minority of committed people. However, there are other ways to promote peer/social learning to increase carbon literacy. One-off workshops and information 'swap shops' might attract people who do not have the time or inclination to join an ongoing group. 'Eco-homes open days' to demonstrate energy efficiency measures, household renewable energy generation technologies and environmental building/renovation work can be valuable (Hamilton and Killip 2009). Attention could be given to the development of online communities, which might be preferred or easier to access than in-person meetings for some people; web-based carbon footprinting tools should enable and encourage information sharing through social media (Bottrill 2007), accessing existing friendship/support groups.

7. Conclusion

This paper has offered a formal definition of 'carbon literacy', useful for both theoretical and empirical purposes, such as designing and assessing interventions to increase carbon literacy. It is analogous to current conceptions of other types of literacy (e.g. financial literacy), and differs from other valuable concepts and tools found in the literature such as 'carbon capability' and the tourism-related 'low-carbon literacy scale' designed by Horng et al. (2013), in that it distinguishes carbon literacy from climate change mitigation action. The

definition I propose focuses on the *ability* to obtain and use information relating to GHG emissions, without determining *how* that information is used.

This does not mean that it is unimportant whether or not individuals reduce their GHG emissions; that is the purpose of promoting carbon literacy. Therefore the paper has also discussed mechanisms that have increased carbon literacy among people who have indeed made (generally significant) reductions in their carbon footprints. This was not a representative sample of the ‘general public’, and it is important not to assume that increased carbon literacy necessarily leads to GHG emissions reductions, but it is nevertheless valuable to distinguish different aspects of carbon literacy and the processes that aid its development. Especially notable is the significance of carbon footprint statements and the value many interviewees placed on learning within a group, which enhanced the energy monitoring that is part of some current UK policies and schemes, such as the rollout of ‘smart’ energy meters nationally (UK Government 2013) and a trial of comparative feedback on energy bills (Cabinet Office 2011). Table 1 makes clear the additional benefits for carbon literacy of these two mechanisms. Given that my findings are limited to a self-selecting and motivated sample, future research could usefully explore how carbon footprint statements and opportunities for peer/social learning to increase carbon literacy could be promoted to a more representative sample, and what effects this might have.

Other areas for future research could include assessment of the costs per tonne of CO₂ abated of carbon literacy campaigns/measures (including the value of individuals’ time in becoming carbon literate), and national differences in carbon literacy requirements given the different energy infrastructures and other services that pertain in various countries. Extensive provision of carbon literacy-enhancing information discussed above depends on government initiatives, energy companies, product manufacturers, retailers and others. Legislation would be required to make emissions information a mandatory part of energy billing or product labelling for goods that do not currently need it, and this might depend on social agreement that this information should be available, which could be another area for research. There are questions to be considered about whether it is realistic to expect widespread development of carbon literacy, given the potential costs, both financially and to individuals who may be fatigued/saturated with health and lifestyle ‘literacy’ campaigns.

It is important to note that the requirements of literacy evolve as society changes (Mason and Wilson 2000); ‘carbon literacy’ is likely to be a dynamic concept, dependent on policies, technologies, and other factors that may introduce new requirements on individuals regarding obtaining and using information relating to GHG emissions. Nevertheless, the definition offered here, while specific enough to be meaningful and to provide a basis for empirical tests of whether particular individuals/groups/populations are carbon literate, is appropriately general enough to accommodate such changes, and will hopefully prove useful to policymakers, educators, and researchers alike.

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Table 1: Mechanisms to increase carbon literacy

Mechanism	Contribution to carbon literacy
Energy (and fuel-use) monitoring	Provides information about home electricity (and fuel) use and related emissions. Supports understanding of CO ₂ emissions associated with use of different technologies and evaluation of options regarding their use or replacement.
Carbon footprint statements	Provides information about various sources of GHGs (e.g. home energy use, travel, food). Supports understanding of comparative GHG emissions of a range of activities and technologies, and evaluation of which activities/technologies to focus emissions reduction efforts on.
Sharing information, resources and skills with others	Helps individuals obtain information about various lower-carbon technologies and activities, including information not available from energy monitors or carbon calculators, without having to do all the information-gathering themselves. Supports understanding of information gained from energy monitoring, carbon calculators and other sources, and evaluation of which activities/technologies to focus emissions reduction efforts on. May enable people to experience/access and develop familiarity with mitigation options through demonstration by/sharing with others.

¹ This definition can be found in the *Introduction to Carbon Literacy* document available to download from the Project's website at www.carbonliteracy.com

² Previously at www.imeasure.org.uk; now rebranded and located at www.piliogroup.com/home-monitoring/

³ www.drupal.org/project/carbon